THERMAL HISTORY OF THE IBITIRA NONCUMULATE EUCRITE: EVIDENCE FOR REHEATING AND FAST COOLING. M. Miyamoto, Mineralogical Institute, Graduate School of Science, University of Tokyo, Hongo, Tokyo 113, Japan.

Introduction: Ibitira is an unbrecciated noncumulate eucrite and shows fine-grained, holocrystalline, and vesicular texture [1,2]. It belongs to an annealing grade of type 5 in which pyroxene is thermally equilibrated [3]. It is generally considered that noncumulate eucrites were crystallized from basaltic melts on the surface of the HED parent body [e.g., 3]. Although Ibitira shows old Pb-Pb ages, Bogard and Garrison [4] reported an ^{39}Ar-^{40}Ar age of 4.495 Ga for Ibitira. This age ranks among the oldest ^{39}Ar-^{-0}Ar ages for eucrites and suggests that Ibitira escaped the widespread impact resetting of K-Ar ages about 4.1–3.5 Ga ago indicated by other HED meteorites [4]. We measured Ca compositional profiles of Ibitira pyroxene by electron microprobe and computed the cooling rate and burial depth from pyroxene exsolution profiles to gain information on thermal history of Ibitira and on the evolution of eucritic crust of the HED parent body [5].

Results: Ibitira pyroxenes have augite lamellae from about 1 µm to 10 µm. A characteristic feature of the Ca profile of augite lamellae in Ibitira pyroxene is a gradient near the interface between augite and low-Ca pyroxene (Fig. 1) [6]. Because this feature cannot be explained by a single cooling, we considered a reheating event.

Pyroxene initially having the uniform bulk Ca content of 15 mol% and mg# (= 100 × Mg/(Mg+Fe)) of 44 begins to exsolve at 1058°C when pyroxene of that composition meets the solvus [7]. Using diffusion coefficients of pyroxene reported by Fujino et al. [8], we obtained the best fit between observed and calculated profiles when the pyroxene cools down to 600°C at a rate of 0.01°C/yr forming an augite lamella about 8.8 µm width (Fig. 1). Cooling time at 0.01°C/yr from 1058°C to 600°C to form the lamella is 4.6×10^4 yrs. The best-fit burial depth is about 800 m in a sheet having a thermal diffusivity of 0.004 cm^2/s, a typical value for solid rock [e.g., 9]. For a thermal diffusivity of 0.00001 cm^2/s which is a value for regolith-like material with ~50% porosity [e.g., 9,10], the best-fit burial depth is about 40 m. For a thermal diffusivity of 0.00001 cm^2/s caused by compaction within the regolith [10], the best-fit burial depth is about 130 m. As seen in Fig. 1, the calculated profile shows a rectangular shape, due to the boundary conditions that the Ca compositions at the interface between augite and low-Ca pyroxene are determined by a solvus function [7]. In fact, observed Ca profiles of augite lamellae in pyroxenes for other eucrites usually show a rectangular shape [e.g., 5].

To better fit the Ca gradients near the interface between augite and low-Ca pyroxene in Ibitira, we assumed a reheating event. After the first cooling that formed the augite lamella, a sudden temperature rise takes place up to above solvus temperature of pyroxene (>1058°C); then the second cooling takes place again at a rate of 80°C/yr from 1100°C. The initial profile of diffusion calculation for the second cooling is the result of the profile computed for the first cooling (Fig. 1). Figure 2 shows the computed profile after the heating event, showing a closer agreement between the observed and computed profiles. The best-fit burial depth is about 10 m for a thermal diffusivity of 0.004 cm^2/s (rock-like), 0.5 m for 0.00001 cm^2/s (regolith-like), and 1.5 m for 0.0001 cm^2/s.

Discussion: At the cooling rate of 0.01°C/yr for the first cooling obtained by the lamella growth (Fig. 1), Mg-Fe zoning in pyroxene is homogenized because the diffusion coefficient of Fe in pyroxene is larger than that of Ca in pyroxene [11]. This result is consistent with the observation that Ibitira belongs to type 5 eucrites, which show no Mg-Fe zoning in pyroxene. This cooling rate is almost the same as that of the Sioux County noncumulate eucrite, although the bulk composition of pyroxene and width of augite lamellae are different [12].

At the cooling rate of 80°C/yr for the second cooling from 1100°C, Mg-Fe zoning of pyroxene is partially homogenized, although Mg-Fe zoning may have been already homogenized during the first cooling.

Reheating temperature is probably above solvus temperature of pyroxene and is below solidus temperature of eucrites (around 1100°C) [13]. We also assume that the augite phase does not exsolve along the solvus function as temperature decreases because of a fast cooling rate (80°C/yr) of the second cooling. This reheating and fast cooling of the second cooling are consistent with the vesicular texture and the presence of tridymite of Ibitira [2]. The vesicular texture can be preserved at the burial depth of the second cooling [1].

The ^{39}Ar-^{40}Ar age of 4.495 Ga for Ibitira [4] may date this reheating event, because the second cooling that alters the Ca profile in pyroxene probably resets the ^{39}Ar-^{40}Ar age. However, we cannot exclude the possibility that the ^{39}Ar-^{40}Ar age may date an event that occurred after this reheating event but did not affect the pyroxene texture. In fact, the ^{39}Ar-^{40}Ar age of the Y75011 noncumulate eucrite, which preserves the pristine nature and is annealing grade of type 1, is largely reset (about 3.95 Ga) [14]. The precise determination of the Rb-Sr age for Ibitira is needed.

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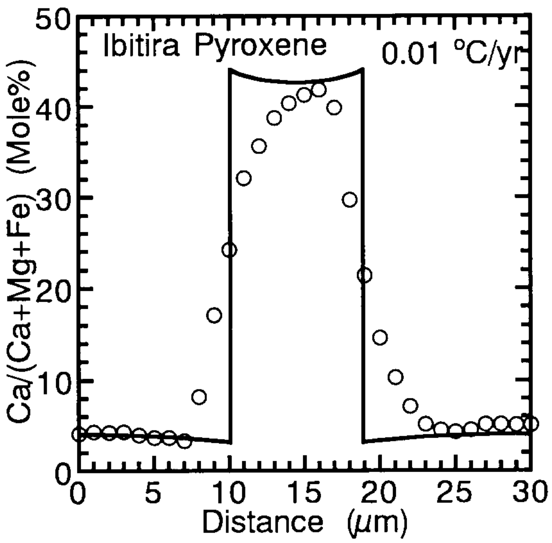

Fig. 1. Observed (open circle) and computed (solid curve) Ca compositional profiles of Ibitira pyroxene. The computed profile is at 0.01°C/yr from 1158°C to 600°C (first cooling).

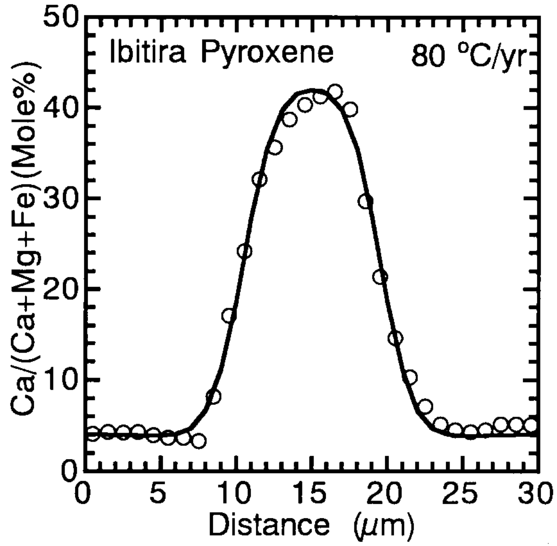

Fig. 2. The computed profile (solid curve) after reheating and the second cooling at 80°C/yr from 1100°C. The initial profile for the second cooling is the computed profile shown in Fig. 1.